13.0 OPERATIONS AND MAINTENANCE COST ESTIMATES

13.1 Introduction

Operating & Maintenance (O&M) costs are addressed separately in this chapter because they are generally the largest category of life cycle cost and complexities of estimating them are considerable. This category of life cycle cost has a number of unique estimating characteristics that warrant separate treatment. One of the unique characteristics is that O&M costs occur over many years. (The actual number of years depends on the life cycle of the item being operated and supported.) Predicting trends in material, parts, and personnel costs and benefits over long periods of time is difficult and makes the O&M estimate more sensitive to assumptions than other types of estimates.

The objective of this chapter is to provide an introduction to the complexities of O&M estimating. There is a discussion of the typical O&M Work Breakdown Structure, a general introduction to typical O&M estimating methods, a brief discussion of O&M cost drivers, and a discussion of O&M models. It is beyond the scope of this chapter to discuss specific factors and relationships that have been developed for O&M cost estimating. While myriad exist, their use will vary by the acquisition category and phase of the life cycle. Furthermore, the FAA IAS has been given the mission to develop databases and methods for consistent estimating, and the estimator will need to refer to them for assistance when an actual estimating task is at hand.

O&M cost estimating is much like other kinds of estimating - estimators must follow the general estimating process. The choice of methodologies is the same as for other estimates - analogies, parametric models, and detailed engineering estimates. However, there are some unique aspects to O&M estimating that justify a separate chapter. This chapter has been divided into sections that cover the topics necessary for a basic understanding of O&M cost estimating. The remainder of this section provides a definition for O&M cost estimating. Section 13.4 discusses unique aspects of O&M estimating and addresses types of O&M cost models. Section 13.5 provides selected model descriptions and information on how to choose a model.

13.2 Integrated Logistics Support Discipline

One of the major reasons that O&M cost estimating is particularly complex is that it is affected heavily by the Integrated Logistics Support (ILS) discipline. The FAA AMS defines ILS as "the functional discipline that deals with the relationship of supportability requirements to the operational requirements, and their consideration in the design of products." (FAA AMS, Appendix E) The discussion in this chapter gives an overview of important concepts that allow an estimator to use tools and data in a more educated manner. The use of an ILS management approach means that early in the planning stages of an acquisition, whether it is developmental or off-the-shelf, the ILS requirements are still being defined. At that early planning stage, there are trade-offs between design and ILS characteristics that will affect the total life cycle costs. This presents the estimator with a great challenge, and a need to understand ILS concepts in order to estimate their impact on life cycle costs to support trade-off analyses during the investment analysis phase. The estimator must understand the ILS parameters and how they affect all elements in the life cycle cost estimate, from acquisition to operations to support costs.

13.3 O&M Work Breakdown Structure

System O&M costs are the added or variable costs of personnel, material, facilities, and other items needed for the operation, maintenance, and support of a system during in-service management. For cost estimating purposes, the convention has been to include only those variable costs associated with system activation and steady-state operation. Disposal costs are expenses associated with discarding the system (excluding salvage value) and are seldom estimated and included as part of O&M costs. Table 13.1 shows the typical O&M cost elements. Of course, the precise WBS will vary with the system being estimated, as will the split of direct and indirect costs in the O&M WBS. The WBS in Table 13.1 is based on the ILS elements listed in the FAA AMS. It also uses input from *FAA Order 1810.3, Cost Estimation Policy and Procedures*, which breaks down operating and maintenance costs more clearly into the two categories of operations cost and maintenance cost. It defines operations costs as those costs that are required to operate the system. Maintenance costs are those costs required to support and maintain the system. All costs must be captured in a life cycle cost estimate, so the WBS contains other cost categories to account for the fact that any given estimate may include unique costs. The estimator also must attempt to capture all direct and indirect costs.

Table 13.0 Typical Operating & Maintenance Cost Elements

WBS Element		WBS Sub-element
Operations		Operations Personnel Support Personnel Other Costs • Supply Support • Operational Facilities • Travel and Transportation • Training and Training Support • Computer Resources Support • Other
Maintenance		Maintenance and Logistics Personnel (Depot, Line, and Contractor Support) Maintenance Personnel Other Costs • Supply Support • Maintenance Support Facilities • Packaging, Handling, Storage and Transportation and Travel • Training and Training Support • Computer Resources Support • Technical Data • Spares • Support Equipment and Spares

Table 13.0 Typical Operating & Maintenance Cost Elements, Cont'd

WBS Element		WBS Sub-element
		Direct and Indirect Other Costs • Utilities • Consumable materials and supplies • Operational facilities • Equipment leases • Communications • Travel • Other

The following paragraphs discuss the O&M WBS and typical estimating methodologies. The reader must bear in mind that estimating methodologies for O&M estimates are the same as those for acquisition programs.

Estimates using analogies, parametric tools, and engineering methods are really no different in O&M estimating. The cost driving variables are different, and they will be discussed in a later section of this chapter.

13.3.1 Operations Costs

Operations Personnel Costs

Operations personnel costs are the wages and benefits paid to the full complement of system operators. For the FAA, system operators are typically air traffic controllers. With the current modernization effort underway at FAA, automation is causing reductions in controller needs. A typical question that an estimator will need to ask is what the impact of a proposed investment will be on operator productivity. System utilization rates and the change in operator productivity can then be translated into the number of operator hours required over the life cycle of the system. A wage and benefits rate is then applied to the estimated hours to generate the total costs of operations personnel. This is a typical approach to estimating personnel costs.

Support Personnel

Controllers have supervisors and a support staff whose costs need to be included in the O&M estimate. The support staff includes programmers, administrative staff, and weather coordinators. The methodology for estimating their costs is the same as for operations personnel, although it is also possible to estimate these personnel costs as an overhead rate applied to the operating personnel workyears.

Other Operating Costs

These include supply support, such as consumable materials and supplies (e.g., fuels and office supplies), travel and transportation costs, training and training support costs, and computer resources support. They also include the costs of operational facilities (e.g., leases, equipment leases, energy consumption, and telecommunications costs).

The other operating costs typically are estimated by multiplying a historical factor by an estimate of usage. For instance, travel costs might be estimated by multiplying the number of miles traveled by an average historical travel cost. Facilities costs may be estimated by a dollar per square foot algorithm.

In the training cost area, training facilities, consumables, personnel, and other costs must be included. The number of operations personnel trained, the amount of time they spend in training, and the costs of their travel to and from training must also be considered as part of the annual training cost. As in many other categories of O&M costs, these types of costs typically are estimated using historical factors. Adjustments, of course, may be required if new equipment is easier to maintain or use.

Energy costs usually are computed by multiplying a cost factor (representing the unit cost of energy in some measure of energy consumption such as kilowatt-hours) by the consumption of energy. Energy consumption needs of new equipment typically are estimated by using existing or analogous equipment and by discussions with technical personnel to adjust for the characteristics of the new equipment. Other regular utility costs related to general facilities and not specific equipment are more of an overhead nature and usually have an established usage pattern.

The types of factors used commonly in O&M estimating are based on costs incurred year to year. An organization should collect these costs in a central cost estimating database and update it as cost information becomes available. Of course, historical rates need to be adjusted for changes that might affect them. For example, consider communications costs. The rapid communications technology changes at FAA mean that historical factors probably will need to be adjusted significantly. With a good O&M cost factor database, the cost estimator's task is simplified.

13.3.2 Maintenance Costs

Maintenance and Logistics Personnel

As with the operations cost category, the maintenance cost category includes direct and indirect personnel costs, and other direct and indirect costs.

The maintenance personnel category of support costs includes the costs of personnel at the depot and at the operating level who are performing maintenance, as well as the costs of supervisory and support personnel. Specifically, maintenance personnel costs include the pay and allowances of personnel performing maintenance at depot and operational facilities.

Repair and maintenance performed at the depot is more complex than that performed at the operating organization. Maintenance activities performed at the depot include:

- Overhaul, conversion, progressive maintenance, modernization, conversion, interim rework, modification, and repair of equipment, and
- The manufacture of parts and assemblies required to support the above.

The number of work hours personnel will spend on maintenance is typically estimated based on some maintainability and repair measure such as mean time to critical maintenance. The result is then multiplied by the average hours spent repairing or maintaining the equipment. A personnel cost factor which captures pay and benefits is then applied to the estimated personnel hours. This is a typical method for estimating direct personnel costs.

Maintenance data like this are collected routinely to help plan maintenance schedules. The FAA IAS should capture maintenance data like this to assist in the cost estimating process. This will facilitate the estimating of such costs for systems in the in-service management phase greatly, providing excellent actual data if the data are captured and maintained properly.

For new programs being considered during IA, the existence of a good database will facilitate estimating and will reduce the time required to estimate. Estimating methods will be very similar to methods used for acquisition - the estimator may use a top-level parametric approach or an analogous system as the basis for the estimate.

Logistics Personnel

Logistics personnel costs include the costs of personnel involved in logistics support, procurement, inventory management, technical data support, and the shipping and handling costs for sending items from the organizational level to the depot and back. These costs often are estimated using historical cost factors and parts condemnation rates.

Other Maintenance and Logistics Costs

The following costs reflect other support cost categories that may be of a direct or indirect nature.

- Supply support such as consumable materials and fuels consumed during maintenance
- Facilities expenses (e.g., leases, utilities, etc.)
- Telecommunications
- Packaging, handling, transportation, and travel
- Computer resources support
- Technical data support
- Replenishment spares,
- Support equipment and spares

- Other.

Most of these categories of cost are the same as those found in the operations section. Some of the costs are unique to the support area such as replenishment spares, replacement support equipment, technical data maintenance and support, equipment maintenance and spares.

Replacement Spares for Programs including Support and Test Equipment

Replacement or replenishment spares costs make up the largest portion of sustaining investment costs for many systems. According to the Air Force Cost Analysis Improvement Group, replenishment spare parts include those repairable components, assemblies, or subassemblies required to resupply initial stock or increased stock for reasons other than support of newly fielded end items. Replenishment would include additional stockage due to usage increases.

Replenishment spares cost estimates typically are based on condemnation, which is based on historical maintenance data. Replacement support and test equipment estimates usually are based on factors that capture experience on similar systems.

In summary, O&M cost estimates generally have some reliability and maintainability measure or system usage rate at their core that allows the estimating of number of personnel required to operate and maintain the system. Other costs are often measured by the use of historical factors applied to the baseline estimate of number of operations and support personnel. These historical factors are types of cost estimating relationships, and can range from very simple to quite complex relationships. The O&M estimate requires good usage rate data, as well as logistics and maintenance data. Over time, as an organization gains experience with its systems and services, this type of data can be captured and refined to the point where O&M estimating becomes relatively routine, such as during the in-service management phase. How well an organization tracks, collects, and maintains data on operating and support costs will make a significant difference in the quality of its O&M estimates.

13.4 O&M Cost Estimating

O&M cost estimating is accomplished by applying many of the same estimating principles and methods used in acquisition cost estimating. There are, however, unique aspects of O&M cost estimating that this section explores.

13.4.1 Unique Aspects of O&M Estimating

In O&M estimating, the estimator will find:

- An O&M Cost Estimating Structure (CES) which differs substantially from the acquisition product oriented WBS

- Heavy reliance on predictive models which tie maintenance and manpower considerations together for long range estimates of costs

- Requirements for 10 to 20 years of projected operational use data to use most models effectively

- Need to consider system constraints extending beyond system hardware (i.e., maintenance manpower, operational environment, spares pipeline times, etc.)

13.4.2 O&M Cost Drivers

When preparing an O&M cost estimate (as part of a life cycle cost analysis or as a stand-alone entity), a number of factors unique to the O&M estimate influence the range and magnitude of the costs to be estimated. Regardless of the scope of the estimating task, six factors always should be considered: equipment life cycle, equipment characteristics, system usage, system activation and deactivation, maintenance concept, and relevant cost elements.

The estimator must determine the quantitative and qualitative impact that each of these factors has on the system being estimated. This process is an important part of defining the system in the planning process. Each of the six factors will be discussed in detail in the following sections. Table 13.2 defines common O&M terms to help the reader understand this discussion.

Table 13.0 O&M Terms and Definitions

Term	Definition
Availability	A measure of the degree to which an item is in an operable and executable state at the start of a mission, when the mission is called for at an unknown (random) time.
Condemnation Spare	A spare obtained to replace an item that is rendered inoperable as a result of the prime equipment operation.
Corrective Maintenance	All actions performed, as a result of failure, to restore an item to a specified condition. Corrective maintenance can include localization, isolation, disassembly, interchange, reassembly, alignment, and checkout.
Cost Driver	An item whose share of O&M costs is disproportionately high.
Line Replaceable Unit (LRU)	An on-equipment replaced item that is repaired at a maintenance level higher than that of the flight line.
Maintainability	The measure of the ability of an item to be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.
Mean-Time-Between Demands (MTBD)	A measure of the system reliability related to demand for logistics support. For a particular interval, the total functional life of a population of an item divided by the total number of item demands on the supply system.
Mean-Time-Between Failure (MTBF)	For a particular interval, the total functional life of a population of an item divided by the total number of failures within the population. A basic (usually contractual) measure of reliability for repairable items.
Mean-Time-Between Maintenance-Action (MTBMA)	A measure of the system reliability related to demand for maintenance. For a particular interval, the total functional life of a population of an item divided by the total number of maintenance actions (preventive and corrective).

Table 13.2 O&M Terms and Definitions, Cont'd	
Mean-Time-Between Removals (MTBR)	A measure of the system reliability related to demand for logistics support. For a particular interval, the total functional life of a population of an item divided by the total number of items removed from that system during a stated period of time. The time is defined to exclude removals performed to facilitate other maintenance and removals for product improvement.
Mean-Time-To Repair (MTTR)	A basic measure of maintainability. It is the sum of corrective maintenance times at any specific level of repair, divided by the total number of failures within an item repaired at that level, during a particular interval under stated conditions.
Not-Repairable-This Station (NRTS)	All reported unscheduled maintenance actions that must be sent to a depot or Special Repair Activity (SRA) for repair.
Reliability	The duration or probability of failure-free performance under stated conditions. Reliability is quantified as the probability that an item can perform its intended function for a specified interval under stated conditions.
Repair Cycle Time	The time span (in calendar days) that begins with the removal of an unserviceable item and ends when the item is made serviceable and ready for use.
Repair Level	Level at which maintenance is performed on an item - organizational, intermediate, and depot.
Scheduled Maintenance	Maintenance performed at prescribed points in time to retain an item in a specified condition by providing systematic inspection, detection, and prevention of incipient failures.
Shop Replaceable Unit (SRU)	An off-equipment replaced item, usually part of an LRU. It can be repaired at a repair shop, but usually is repaired at the depot.
Spare Backorders	Spares orders not filled for lack of spares.
Spare Pipeline	The inventory of spares required to meet an established system availability requirement. Inventory is a function of item reliability, repair cycle time, and the established availability requirement.

Equipment Life Cycle

Every item of equipment has an expected useful life determined by one of three factors - technological considerations, mission requirements, or physical characteristics. From a technological standpoint, systems are useful up to the point where technology makes them obsolete. Physical characteristics (e.g., the inherent wear-out mechanisms in systems) eventually make support and repair impractical. For O&M cost estimating, the useful life of a system or an equipment item is considered to be the shortest of its technological, mission, and physical life. Incidentally, the value picked is commonly referred to as economic life. *OMB Circular A-76*, *Appendix C,* provides suggested economic lives for selected assets. In addition, the FAA's Special Topics paper, *Choice of Economic Service Life (ESL) for FAA Analysis Purposes,* dated September 29, 1998, provides guidance on this topic. The FAA paper is available on FAST.

Equipment Characteristics

Defining the system includes determining a number of equipment characteristics that impact O&M costs, such as:

- Design and physical parameters such as weight, size, design approach, degree of modularity (e.g., LRU, SRU)
- Required performance characteristics such as reliability and maintainability, availability, redundancy levels, etc.
- Required interfaces with other systems, equipment, and support equipment
- Unusual training, operations, and support requirements
- Unusual testing or certification requirements
- Required level of technology
- Known, similar systems

Equipment characteristics such as reliability, maintainability, size, and weight often are used in parametric O&M cost estimation, since they are strongly related to O&M costs. MTBF, a measure of system reliability, is used to predict the frequency at which maintenance and supply actions will occur. MTTR, a measure of system maintainability, is used to predict the duration of repair actions. Together, reliability and maintainability information form the basis for determining recurring labor and material costs associated with maintenance and supply.

A number of cost estimating relationships (CERs) use physical attributes such as size and weight in the estimation of inventory and transportation related costs. Examples of such costs are the costs of packaging inventory for shipment between operational and maintenance facilities, handling assets before and after shipment, shipping assets between facilities by various modes of transportation, and storing the assets prior to use.

System Usage

System usage, or usage rate, is defined as the expected or planned use of the asset per unit of time. This rate is expressed in terms of operating hours per month or year, and in most cases reflects steady-state operations. When developing usage rates for a system, the estimator should consider anticipated surges. Surges are intermittent additional usage requirements over and above steady-state rates. An increase (decrease) in usage produces a corresponding increase (decrease) in total O&M cost. Most O&M cost elements vary linearly with usage. For instance, the number of system operator hours will vary linearly with usage. However, there are elements that are more independent of usage. Fixed costs such as item management, facilities, and technical data are constant regardless of usage. Semi-variable costs, such as maintenance personnel, may vary only as specific thresholds are exceeded.

System Activation and Deactivation

FAA's program phases are investment analysis, solution implementation, in-service management, and disposal. Although program phases generally are considered sequential, sometimes overlap occurs, especially between solution implementation and in-service management. During the solution implementation phase, systems normally are deployed on an incremental basis, and activation of systems takes place shortly thereafter. Activation of all systems can take as little as a few months or as long as five to ten years, depending on the program. The start of the activation period generally is considered the beginning of the in-service management or O&M phase. During the activation period, O&M costs increase with the total number of systems activated. This ramping up of O&M costs continues until all systems are activated, concluding the activation period. From this point on, O&M costs level off until the end of the system's economic life. As systems are deactivated during retirement, O&M costs ramp down until all systems are deactivated. Certain cost elements are applicable only during the activation phase; initial transportation and facility construction/preparation are two such examples.

Maintenance Concept

The maintenance philosophy, or maintenance concept, defines the means of maintaining a system or equipment item. It includes maintenance levels to be used with major functions accomplished at each level, basic policies, and primary logistic support requirements. The maintenance concept usually is defined at program inception and is refined over the system design and development phase. The maintenance plan formally documents the maintenance concept, defining in detail the procedures and resources necessary for the support of a system.

Determining the maintenance concept of the system under study requires answers to the following questions:

- Is there a warranty?
- Is the system under a two-level or a three-level maintenance policy?
- Are there any special maintenance activities?
- Does the system receive Interim Contractor Support (ICS)? At intermediate-level? At depot? For how long?

A major component of maintenance concept definition is the structure of maintenance levels to be used in support of the system. Maintenance, both corrective and preventive, may be accomplished at the site where the system is used (organizational level), and/or at a depot or manufacturer's plant facility (depot level). Tasks and functions are divided among any or all of these levels; division is primarily dictated by task complexity, personnel skill level requirements, and special facility needs. Each acquisition program has an Integrated Logistics Support Plan that should identify the maintenance levels.

Also important to the O&M cost estimating process is quantifying the type and level of maintenance resources required for the system. The principle maintenance resources are spares; petroleum, oils and lubricants (POL); support equipment maintenance manpower; facilities; and computer resources.

Once the estimator has defined the major characteristics of the system, the O&M estimator will continue following the normal estimating process. After a plan is in place, the estimator will lay out the estimating structure, which involves outlining the expected O&M cost elements. Then, the estimator will select methodologies and conduct data research and normalization. This step also includes, as the reader may recall, risk analysis.

13.4.3 O&M Risk Analysis/Trade-off Analysis

O&M risk analysis differs from other cost estimating risk analyes because the cost drivers differ. Knowing the cost drivers and understanding their relationship to cost is important in O&M estimating because decision makers, at least early in the life cycle, require information regarding design and O&M cost trade-offs. It is very common to do sensitivity analysis on the key cost drivers to see the trade-off of design factors on cost.

As an example of a cost trade-off, consider the cost sensitivity of an advanced fire control system to both reliability (as measured by MTBF) and maintainability (as measured by repair times). The cost trade-off analysis may show that a shortfall in field reliability of 33 percent (from 33 to 22 hours) will yield a 50 percent increase in maintenance and spares cost ($100 million increase). Conversely a doubling of the repair times at the baseline reliability value will result in only a $15 million (7.5 percent increase) in maintenance and spares cost. Thus, it can be concluded that reliability represents a greater cost risk than maintainability. From this analysis, decision makers might conclude that they should place emphasis on monitoring and improving reliability since greater potential cost savings can be obtained.

Trade-off analyses are also important to logistics decisions impacting the maintenance concept and investments in support resources, such as spares and support equipment. Perhaps the most common trade-off analysis is Level of Repair (LOR) type analysis, also commonly known as two- versus three-level maintenance analysis. Trade-off analysis often involves varying a set of parametric values in order to determine break-even values. For example, equipment reliability (as measured by MTBF) can be varied over a wide range of values while varying the investment cost in support equipment (e.g., quantity of testers at intermediate-level). Two- versus three-level analysis can be conducted under these conditions to determine the equipment MTBF break-even value where one maintenance policy becomes more costly. In general, the lower the support equipment investment, the higher the system MTBF needs to be for a two-level policy to be cost effective.

13.5 O&M Cost Models

Many cost models are used to perform analysis of O&M costs. Most are designed to fulfill a particular need. Some cover life cycle costing overall, while others are devoted wholly to acquisition costing, O&M costing, or a mixture of both. Since describing all O&M related models is beyond the scope of this chapter, the models described in the next section are representative types of models. Section 13.5.2 gives the reader tips on how to find O&M cost models and Section 13.5.3 describes some commonly used models. Finally, Section 13.5.4 gives tips on cost model selection.

In *O&S Cost Estimating - A Primer*, Thomas May warns that "one of the major pitfalls that trap many cost analysts is placing too much emphasis and time on developing a highly complex model that is peculiar to their program."" Fortunately, the cost estimator can often short cut the analysis process by fitting data into existing O&M models. The following sections review general types of O&M models and introduce commonly used models. The focus is on DoD-developed models because this is where much of the activity in estimating major systems acquisition costs has been and therefore where most of the cost models have been developed. It should be emphasized, as mentioned before, that existing cost models generally have been created for specific uses or systems. The following discussions simply provide the estimator with insight into what to look for in building models.

13.5.1 Types of O&M Cost Models

There are three general categories of models used in O&M estimating – the engineering model, the parametric model, and the simulation model. Of course, as in any kind of estimating, it is typical to use a combination of estimating methods. For instance, many engineering models require input that might be the output of a parametric model.

Engineering Model

An engineering model contains a set of equations used to aggregate elements of O&M costs. Costs may be computed by multiplying item costs by quantity, or by applying factors to system parameters, gross costs, and requirements. These models are useful when estimating O&M costs for an entire system; they may sometimes be used to aggregate subsystem O&M costs developed by the more complex parametric models discussed later. An example of an equation you might find in an engineering model follows.

$$WR = [EQL(LH/\ YR)] \bullet (ELE\text{-}Dollars/LH)$$

Where:

PWR = Annual site electrical costs
EQL = Average equipment load in kilowatts per hour
LH/YR = Average electrical load hours per year
ELE-Dollars/LH = Cost of electricity per load hour

Parametric Model

This type of model uses CERs developed from an analysis of historical data of similar systems. The available models range from those that use simple factors to those that employ sophisticated

CERs. The more complex models employ equations relating O&M cost elements to parameters that describe the design, performance, operating or logistics characteristics, or environment of a system. The CER type of model is particularly appropriate at early program stages when only top-level system data are available.

In the case of a factor-based model, factors are developed that relate known input costs or parameters to costs being estimated. The following is a sample equation drawn from a well-known factor based O&M estimating model.

$$TAH = (T\&E\ MH) \bullet (T\&E\ RATIO)$$

Where:
(maintenance programs)
= 0.035 (communications programs)

TAH = Man-hours to system-test modified software
T&E MH = Man-hours to test software in lab
T&E RATIO = 0.030 (controller programs)
= 0.050

More complex analytic models should be used only when there is both a detailed system definition and substantial operational data. Some analytic models work best for specific subsystems rather than an entire system. Below is an example of an equation found in an analytic model.

$$FMC_i = \sum_{m=1}^{12} \left[\left(NCUM_{(k,m)} \bullet OH \bullet NQ_i \right) / \left(\left(1\text{-}OFP_i \right) \bullet G_{(k,m)} \bullet MTBF_i \right) \right] \bullet RRS_i \bullet SBR$$

Where:
FMC_i = Annual maintenance cost for a unit i (where unit i is an LRU, SRU, or sub-SRU)
$NCUM_{(k,m)}$ = Cumulative number of systems installed by month of year k
OH = Average operating hours per month per system
Nq_i = Quantity of unit i required in system
UFP_i = Expected fraction of removals of unit i that will be unverified failures
$G_{(k,m)}$ = Ratio of the system MTBF achieved in month of year k to the initial system
MTBF $MTBF_i$ = Mean Time Between Failure of unit i
RRS_i = Average labor in man-hours required to isolate a failure to unit i, remove it, replace it, and verify the corrective action
SBR = Standard base labor rate in dollars per man-hour

Source Model: Life Cycle Cost Analyzer (LCCA).

Simulation Model

A simulation model uses computer simulation to determine the impact of a system's characteristics, operational constraints, basing concept, maintenance plan, and support resource requirements on operations and support costs. These models generate statistical results based on hardware parameters such as reliability and maintainability. Simulating the system life through analytic models and statistical distributions generates computed O&M costs. These models assume that system performance and maintenance can be simulated with statistical distributions, and require the user to input parameters for the distributions.

O&M estimates often are very detailed estimates simply because of the nature of operations and maintenance, such as the requirement for numerous spares and piece parts. Also, the common predictive models, used heavily for O&M cost estimating, make use of detailed input parameters, thereby producing detailed output.

13.5.2 Finding Information on O&M Cost Models

There are many O&M cost models available, particularly in the DoD. The estimator should research some of the following sources in the search for a good model to use.

The Supportability Investment Decision Analysis Center (SIDAC) is an Information Analysis Center sponsored by the Air Force Materiel Command to increase the effectiveness of logisticians, engineers, and managers engaged in the support of DoD systems. SIDAC has composed a 600-plus page compendium of supportability models, titled *The Supportability Model Catalog.* This two-volume set features detailed information on over 100 active models, including the model's history, scope, mission, reliability, etc. Also enclosed is a list of over 50 models that are considered to be obsolete. Information concerning SIDAC can be obtained from http://www.sidac.wpafb.mil/reprt.html #model.

The Defense Logistics Studies Information Exchange (DLSIE) has the mission of collecting, organizing, storing, and disseminating information relating to the DoD logistics study effort and logistics management documentation. The principal method of disseminating information relating to the current logistics studies effort is through the *Annual DoD Bibliography of Logistics Studies and Related Documents.* DLSIE also produces the *Annual DoD Catalog of Logistics Models.* See http://www.sidac.wpafb.mil/data_sys/dlsie.html for DLSIE information.

13.5.3 Selected Model Descriptions

Table 13.3 Summary of O&M Cost Models

Name of Model	Type of Model	Outputs	Inputs

Logistics Support Cost (LSC) Model http://www.sidac.wpafb.mil/models/catelog/modcat.html	Engineering with CERs	Hardware estimated: primarily avionics Costs estimated: depot maintenance, spares, transportation costs, subsystem to system level	SRU and LRU reliability and maintainability factors
Life Cycle Cost Analyzer (LCCA) http://www.sidac.wpafb.mil/models/catelog/modcat.html	Parametric	Hardware estimated: complex avionics, test equipment, electronic warfare systems Costs estimated: Subsystem to system maintenance, spares, supplies, facilities, training	Significant amount of low level reliability and maintainability data
Cost Analysis Strategy Assessment (CASA) Model http://www.logpars.army.mil/casa	Engineering	Hardware estimated: aircraft Costs Estimated: R&D, acquisition, and all O&M cost elements	Detailed data on maintenance characteristics of hardware LRUs and SRUs, extensive detail on maintenance support structure
Standardization Evaluation Program (STEP) Model http://www.sidac.wpafb.mil/models/catelog/modcat.html	Engineering	Hardware estimated: aircraft avionics Costs estimated: three levels of maintenance costs, software maintenance, support equipment maintenance, replenishment spares, packing and shipping costs	Detailed data on maintenance characteristics of hardware LRUs and SRUs, depot attributes, and support equipment attributes

Table 13.3 Summary of O&M Cost Models, Cont'd

Name of Model	Type of Model	Outputs	Inputs
Network Repair Level Analysis (NRLA) Model http://www.sidac.wpafb.mil/models/catelog/modcat.html	Level of Repair Analysis Model, allows quick and easy sensitivity analysis of LRU, SRU, and support equipment costs	Recommended repair level decision and cost of decision	Detailed data on maintenance characteristics of hardware LRUs and SRUs, depot attributes, and support equipment attributes
Cost Estimating for Logistics Support Analysis (CELSA) http://www.logpars.army.mil/alc/webCelsa/celsa.htm	Simulation delphi technique to estimate the cost of doing an LSA program.	Estimated man-hours required to complete a LSA task or subtask.	Type of acquisition, life cycle phases, support concept, type of system/equipment, complexity of system/equipment
Joint Operating and Support Technology Evaluation (JOSTE) Model http://www.sidac.wpafb.mil/models/catelog/modcat.html	LCC and O&M computations for new or existing systems, any acquisition phase, for various technologies	System sensitivity, total LCC, annual costs, detailed subsystem costs	Can transfer external system databases into the model database for analysis, availability, maintainability, repair level

13.5.4 O&M Cost Model Selection

Each O&M model has unique characteristics and level of acceptance for specific uses. Therefore, one of the most critical steps in preparing an O&M cost estimate is that of selecting an appropriate model or methodology.

- Step 1: Determine Needs

The selected O&M cost model generally will be a compromise of more than one model. However, a cost estimator responsible for a total life cycle cost estimate should review the O&M cost estimating requirements and answer the following questions:

- What output values are required?

- What are the input parameters to which the output values must be sensitive? Are the data available to provide this input?

- Are absolute or relative estimates more appropriate for meeting the study objectives?

- What model has been used successfully and accepted recently for similar work?

- What (if any) model was used previously for estimating the O&M costs of the same system?

- Do the O&M activities for the planned system involve any unusual conditions or assumptions?

- Does official direction or precedent exist with respect to what O&M estimating methods must be used?

Prepare a matrix for evaluating each model on each criterion with respect to the analysis needs.

- Step 2: Select Candidate Models
  Review the available O&M cost model description and give a rating with respect to each evaluation criteria. Review the completed matrix to eliminate totally unsatisfactory alternatives and to select an acceptable or best marginal alternative.

- Step 3: Choose Appropriate Model
  Coordinate the model selection with those who will be major users of the analysis results.

- Step 4: Reevaluate Model Choice
  User needs, support concepts, and models change over time. Therefore reevaluate the model being used every few years to insure that it remains the most suitable for the cost estimates required by the program.

- Step 5: Review the completed matrix to eliminate totally unsatisfactory alternatives and to select an acceptable or best marginal alternative.

- Step 6: Coordinate the model selection with those who will be major users of the analysis results.

13.6 Summary

The decision to field a new system requires a commitment to support that system for years into the future. Decisions to develop, procure, and support new systems are based on many factors, one of which is the projected cost of the systems over their operational lifetime. O&M costs normally constitute a major portion of system life cycle costs and, therefore, are critical to the evaluation of acquisition alternatives.

Operations and support costs include all costs of operating, maintaining, and supporting a fielded system. Estimates of O&M costs generally are prepared using previously developed cost models. As a guideline, this chapter has introduced some of the existing models and provided model selection criteria.